Evaluating the investment in pruning in the Lake Taupo and Lake Rotoaira Forest Estates

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Abstract

Pruning has been a major part of forest management since the early 1950s carried out to produce clearwood in the butt section of the stem. Pruning regimes are more intensive and require additional management compared to no pruning, this in turn generates additional costs during the rotation. The economics of pruning has become a controversial topic in recent times, as many large scale owners (Timberlands) have stopped pruning completely. The Timberland's estate is adjacent to the Lake Taupo and Lake Rotoaira Forest estates and trustees have begun to question their silvicultural investment in light of Timberland's recent decision. This dissertation aims to analyse the economics of pruning within the Lake Taupo and Lake Rotoaira Forest estates.

As of 2018, 98% of the pruned log supply was sold domestically while the remaining 2% was exported. In the same year, 44% of the unpruned log supply was sold domestically while the remaining 54% was exported. This suggests that the main outlet for pruned logs is the domestic market, while the main outlet for unpruned logs is currently split between the domestic and export markets. All pulp logs are currently being sold to the domestic market.

Domestic customers are vital in terms of selling the log grade mix produced from the trusts estate. Currently there are three main pruned log customers, two main unpruned log customers and two main pulp log customers located in and around the Central North Island.

Based on land expectation value the two lift pruning regime is the most profitable regime on all four sites analysed (low, medium, high and very high productivity). The difference in land expectation value between the two lift pruning and unpruned regime is minimal on low to medium productivity sites. This difference increases as site productivity increases (high and very high), which suggests that pruning should be confined to the high productivity sites as this generates a better financial return for pruning regimes. The investment in pruning is extremely sensitive to changes in prune log price and tending costs, with minor changes in each variable having a significant influence on the overall profitability. The three lift regime is the least profitable regime which supports the trusts decision to shift to a more profitable regime in 2014 (2 lift prune). The analysis has artificially favored the two lift regime, as log prices do not account for the better pruned log index that is achieved under the three lift pruning regime.

Acknowledgements

This dissertation project would not have been possible without the help and support of many individuals and company entities. With that in mind, I would like to acknowledge those who have been a part of this dissertation project.

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1. Introduction

The Central North Island (CNI) wood supply region spans from Bombay in the North, Taumaranui in the West, Turangi in the South and Lottin Point in the East (Tombleson, 2018). The CNI has a total forested area in *Pinus radiata* (radiata pine) of 551,875 ha, 36% (198,348 ha) of which is pruned to a height of at least 4 m (Ministry for Primary Industries [MPI], 2018).

The Lake Taupo and Lake Rotoaira Forest Trusts (LTFT/LRFT) own and administer land on behalf of the owners and beneficiaries of the Ngati Tuwharetoa Iwi. Lake Taupo Forest (LTF) and Lake Rotoaira Forest (LRF) are currently under a Crown lease arrangement which is set to expire in 2020 for LTF and 2025 for LRF. New Zealand Forest Managers Ltd. (NZFM) currently manage both estates on behalf of the Crown. In 1973 the land of both estates was originally leased to the Crown for 70 years (2 rotations), with the land being returned to the trusts after the harvest of the second rotation. This agreement was changed to a one rotation lease in 2002.

LTF spans from the Waitahanui stream in the North to the Turangi Township in the South and runs between the shores of Lake Taupo and the Kaimanawa ranges. LTF has a net stocked area of 22,370 ha in Radiata pine, 76% (17,001 ha) of this area has been pruned. LRF borders Lake Rotoaira and the Desert Road (SH 47), the estate has a net stocked area of 9,124 ha, 63% (5,748 ha) of this area is pruned. Most of the pruned area has been pruned under a traditional three lift regime with a target height of 8 m, while the more recent pruned area (post 2014) has been pruned under a two lift regime with a target height of 5.5 m. The geographic location of each estate is shown in Appendix 2.

Pruning has been an important part of forest management since the early 1950s carried out to produce high quality clearwood. General trends in New Zealand (NZ) silviculture show that pruning regimes are becoming increasingly less popular. This is evident in the CNI with NZs largest supplier of pruned logs (Kaingaroa Timberlands Ltd) shifting away from pruning regimes in 2015. Timberlands decision has sparked concern among trustees of the neighboring LTF and LRF estates regarding their current silvicultural investment.

This project aims to evaluate the current silvicultural investment within the LTF and LRF estates, focusing on three silvicultural regimes; unpruned, two lift and three lift pruning.

Recommendations will be made regarding the economics of pruning, regime selection and domestic/export markets, to aid in the decision making process of future silvicultural investments.

2. Problem Statement

The general trends in NZ silviculture show that pruning operations are becoming increasingly less popular, this shift in popularity is evident in the CNI. Since 2009 the pruned area within the CNI has decreased from 286,960 ha to 198, 348 ha as a direct result of many forest owners choosing to reduce or completely stop running operations (MPI, 2018).

In 1996, large corporate growers such as Carter Holt Harvey Forests Ltd and Kaingaroa Timberlands Ltd changed their management approach towards regimes that did not involve pruning. Timberlands has since extended this type of regime across their whole estate, stopping all pruning operations in 2015 as this was believed to be the most profitable decision (Ministry of Business, Innovation & Employmnet [MBIE], 2018). The Timberlands estate is adjacent to the LTF and LRF estates. Timberland's management decision has sparked concern among trustees, regarding the current silvicultural investment within the LTF and LRF estates. This study aims to evaluate three silvicultural regimes on an economic basis to provide an insight into the profitability of pruning regimes.

The project is relevant to the LTF and LRF trusts, given that pruning operations have been a major part of the management in both estates. It is also relevant when considering the employment that pruning operations provide to local people and the potential cash flow tradeoffs between pruned and unpruned regimes. The project is also relevant from a strategic point of view, which could potentially place the LTFT and LRFT as the main suppliers of pruned logs in the CNI if pruning continues.

2.1 Research questions

1. What is the demand for pruned, unpruned saw logs and pulp logs in the LTF and LRF estate from domestic and international customers?
2. Which silvicultural regimes best match 4 site types in the LTF/LRF estates, based on productivity using 300 index values (low (27) , medium (29), high (31), very high (33))
    - Unpruned
    - Two lift pruning
    - Three lift pruning

3. Literature review

Relevant literature to the dissertation topic has been reviewed to broaden the understanding around pruning operations carried out in NZ plantation forestry, and how these operations have evolved since the 1950s. This has provided the necessary background to understand the wider influences that impact the decision to prune. Literature regarding the economics of pruning in NZ is limited to historic research carried out in the early 1950s, however, the underlying principles are still relevant in today's operations. The literature review has been broken into the following sections:

- History and background of pruning in NZ
- Evolution of pruning operations
- Pruned log value
- Trends in management

3.1 History and background of pruning in NZ

In plantation forestry, pruning is the process of removing branches flush with the stem to produce knot free timber (clearwood). Although branches are important for grow and survival, they form knots which degrade the overall quality of the timber (Shepherd, 2012). Pruning is generally carried out in the lower butt section of the stem using loppers and a ladder during the early stages

of growth (years 5-10), to minimise the diameter of the defect core and to maximise clearwood growth.

Pruning regimes were first adopted in the early 1950s with bulk of the operations and early trials being carried out in the CNI. Radiata pine has traditionally been managed as a direct saw log regime that yields pruned logs or a structural regime that does not yield pruned logs (MBIE, 2018). Direct saw log regimes are more intensive as a result of multiple pruning lifts, which adds additional costs over the course of the rotation in order to produce a pruned log (Beehre, n.a). The popularity of these regimes has drastically changed over time with many forest owners shifting away from direct saw log regimes as the gain in value does not always compensate the loss in volume.

3.2 Evolution of pruning regimes

Intensive pruning and thinning operations were a major part of forest management between 1950 and 1980, where the main objective was to produce high-quality clearwood. Since the 1950s pruning and thinning operations have become more selective, as the general focus of forest owners has shifted from clear wood production towards maximising the return on investment (Laurie Forestry, 2019). Pruning regimes have evolved significantly in terms of scheduling, pruned height, final crop stocking, defect core specifications, and the number of lifts carried out. This evolution is evident in LTF and LRF, where a transition has been made from a three lift pruning regime with a target height of 8 m towards a two lift pruning regime with a target height of 5.5 m.

In many forest estates a traditional three lift pruning regime with a target height of 5.5 – 6.5 m has been carried out. A series of three lifts can be prohibitively costly due to factors such as initial stocking, branch size, equipment, hindrance and pruned log prices (Fenton, 1971). The early pruning regimes often required two or three pruning lifts to meet the following specifications (Lewis, Fergusson, Sutton, Donald, & Lisboa, 1993):

- Defect core specification of 15 cm maximum diameter
- Minimum radius of 10 cm for clearwood
- Pruned height of 4.8 – 5.5 m

The concept of ultra-high pruning (second log) was trialed across 3,030 ha of State plantations between 1959 and 1970 with a target height of 11 m (Fenton, 1973). It was concluded that second log pruning was less profitable than an unpruned regime due to the long rotations that were required to obtain large diameters with sufficient clearwood growth. Pruning regimes that focused on the butt log (6-8 m) proved to be the most economic investment due to the high volume yield of the butt log (Fenton, 1973). In today's pruning regimes, managers typically aim for a final pruned height of 5.5 - 6.5 m which is higher than that of the early regimes (4.8 - 5.5 m). A pruned height of 5.5 - 6.5 m is also more profitable than pruning to 11 m which is evident in Fenton's research.

3.3 Pruned log value

A pruned log can be defined as the section of stem between the stump and the first whorl of branches (Beehre, n.a). The clearwood produced in pruning regimes sells at a premium price, as it can be turned into high quality wood products such as long-length clears which are then used in high end applications such as millwork, windows and doors.

The amount of clearwood that can be converted to high grade timber is dependent on log size, log shape, and the size of the defect core (Park, 1989). These factors are directly influenced by the quality and timing of pruning operations. If pruning operations are well executed and carried out on time, the value of the pruned butt logs can be worth the aggregate of all other logs produced, subject to log prices. If pruning operations are delayed there is potential for defects to develop, such as occlusion scars which degrade the clearwood quality and overall value of the pruned log (Somerville, Park, & Goulding, 1985). Clearwood growth is heavily influenced by factors such as silviculture, site productivity, and rotation length. The value of clearwood is influenced by external features such as sweep buttressing and fluting. It is also influenced by internal features such as resin pockets, pith centrality, and density (Somerville, Park, & Goulding, 1985). The price premium for pruned logs can often limit the profitability of pruning regimes, as this premium must be high enough to cover the initial pruning investment. In theory, pruned logs should be priced according to Pruned Log Index (PLI) values, this would price each log based on quality. PLI is

predicted using measurable log variables such as log size, log shape, and the size of the defect core (Park, 1989).

3.4 Trends in management

Silvicultural practices have been influenced by landowner objectives and the objectives of the NZ forestry sector (Kirkland, 1976). Since the 1950s, many forest owners have shifted from producing appearance grade logs towards maximising the volume per hectare, by stopping pruning operations and thinning less severely. Currently, 198,348 ha is pruned in the CNI which is 88,612 ha less than what was pruned in 2009. Direct saw log regimes involve two to three pruning lifts to remove the branches on the lower section of the stem, with an indicative final crop stocking of 228 stems/ha (MBIE, 2018). This type of regime has become less popular among large scale forest owners such as Timberlands, who now no longer prune any of their stands.

The shift towards unpruned regimes is driven by the increase in net return per hectare at the time of harvest as a result of not having to carry the cost of pruning over the course of the rotation (Tombleson, 2018). Pruning still remains a viable option for some of the smaller-medium scale owners, who without the pruned log component would struggle to make forestry a feasible investment due to the high transport cost associated with trucking unpruned logs which are often destined for the export market. (Tombleson, 2018). This illustrates the trade-off that comes with pruning, as forest size may be a key factor in deciding whether or not to prune.

Trends in the pruned log premium have declined over time making it hard for many companies to justify the cost of pruning and the subsequent loss in volume per hectare. The price premium is a key factor in deciding whether or not to prune. Timberlands required an additional premium of US 30-40 USD/m^3 to justify the pruning investment (MBIE, 2018). Their decision in 2015 to change from pruned to unpruned regimes was driven by a view that the pruned log premium was unlikely to recover based on historical trends.

4. Data and Methods

4.1 Data

The analysis includes the following data that is confidential to the LTFT and LRFT.

- Log sales records from the LTF and LRF estate
- Costing information

The log sales records contain specific data on sales volumes, revenue, transport cost, log and load cost and stumpage to domestic and international customers. The historic data has been provided on a monthly basis between September 2007 and March 2019 (12 years). For the ease of analysis the monthly data has been summed across the relevant quarters of the financial year. The log sales records have been used to derive domestic and international demand in order to analyse the key markets for pruned, unpruned sawlogs and pulp logs. Data contained in the log sales records has been used to generate the following information:

- Domestic and international demand by log type using actual sales volumes (m^3)
- The proportion of total log sales split between the domestic and export market (%)

Costing information has been provided on a yearly basis and is split between pruned and unpruned regimes based on site productivity (low, medium, high, and very high). This information details the specific operational costs associated with each regime. Costing information accounts for site preparation, establishment, pruning and thinning. The annual overhead cost has also been provided which is a function of the following costs; administration, maintenance, rates, fire and protection. Annual and operational costs have been provided on a dollar per hectare basis. Harvest costs have been provided based on the following systems; skidder, tractor and swing yarder. These costs are a function of piece size, provided on a dollar per cubic meter basis. Costing information has been used in the discounted cash flow analysis to evaluate the economics of each regime.

NZFM have provided the starting values for modelling the silvicultural regimes in Forecaster (version 2.2.0.1537). The starting values include information on sites, crop types, regimes, log product definitions and cutting strategies for each estate.

4.2 Methods

To investigate the demand for pruned, unpruned saw logs, and pulp logs, the domestic and international demand for logs from the trusts' estates has been analysed using Microsoft Excel 2016. The analysis has been split into the following components:

- Proportion of log sales sent to the domestic and export market
- Volume supplied to domestic and international customers by log type.

Log sales volumes were totalled across both estates and split between domestic and export sales as a proportion of total log sales, on a yearly basis between 2008 and 2018 (10 years). Actual sales volumes (m^3) were extracted by log type (pruned, unpruned saw logs, pulp logs) and presented as volumes supplied by both estates across the same time period.

The domestic demand by log type has been further analysed to derive the most important pruned and unpruned saw log customers in the CNI. This was based on the relative sales volume to each customer over a 12 month period between April 2018 and March 2019.

On-truck log prices ($/$m^3$) for the main log grades produced by the LTF and LRF estate have been calculated using the revenue, transport cost and volume associated with each log grade. The on truck log prices have been used as log prices in the discounted cash flow analysis. On-truck log prices were also used to calculate the pruned log premium price over export a grade logs, based on a 12 month average price between April 2018 and March 2019.

To investigate which silvicultural regimes best match 4 site types in the LTF/LRF estates, I examined different regimes at sites of values low (27), medium (29), high (31), and very high (33) productivity. Specifically, Forecaster (2.2.0.1537) was used in conjunction with starting values provided by NZFM to evaluate an unpruned, two lift pruning and three lift pruning regime across the four different sites based on 300 index values. Values ranging from 27 to 33 best represent the following range of site productivity; Low (27), Medium (29), High (31), Very High (33). An average differential between site index and 300 index were used to estimate the relative site index values that correspond to the 300 index values above. This differential is calculated based on 30 points selected in each estate.

Forecaster generated yield tables and silvicultural tending information for each estate. This information was used to complete a discounted cash flow analysis using a model modified from one generated by Bruce Manley (School of Forestry). This analysis utilises the costing information above. The Land Expectation Value (LEV) has been used to assess the profitability of each regime.

Forecaster also predicted Pruned Log Index (PLI) values for each of the pruning regimes. The PLI values were compared between both pruning regimes to illustrate the difference in pruned log quality achieved under each regime.

To test the effect that independent input variables have on the LEV of each regime a sensitivity analysis was carried out. This analysis targeted the following input variables; discount rate, pruned log price and silvicultural tending costs. Each input variable was adjusted and the difference in LEV between the two lift pruning and unpruned regime recorded, to determine the point where pruning is no longer profitable.

4.2.1 Assumptions of the analysis

4.2.1.1 Forecaster analysis

- The four sites selected based on 300 index values (27, 29, 30, 33) are representative of the range of site productivity within the LTF and LRF estate
- Log prices do not account for specific PLI predictions
- Log grade specifications and the chosen cutting strategy are shown in Appendix 3. The cutting strategy is based on a priority list
- Log grade specifications are derived from actual grades produced in the LTF and LRF estates.

4.2.1.2 Discounted cash flow analysis

- A discount rate of 7% was applied to pre-tax cash flows in the DCF analysis. This discount rate is within the range of discount rates surveyed in 2018 for forest growers in the CNI (Manley, 2019)
- The cost of each pruning lift under the three lift regime has increased by 38% since 2014
- Overhead costs from the 2018/2019 financial year are representative of future costs
- On truck log prices were used to account for transport distances to different customers
- The 12 month average on truck log price is representative of future log prices as shown in Appendix 4
- Silviculture costs from years 0-10 are shown in Appendix 5
- Harvest costs were modelled using a polynomial regression. The costing model is based on a skidder system as shown in Appendix 6

5. Results

5.1 Annual log sales

The combined total log sales volume from the LTF and LRF estate varied between 2008 and 2018 with a minimum of 664,639 m^3 and a maximum of 861,300 m^3 (Figure 1). In terms of net stocked area the LTF estate is 13,246 ha larger than the LRF estate, therefore, most of the annual log sales volume is accounted for by the LTF estate. The total log sales volume in 2018 totaled 709, 503 m^3. LTF accounted for 67% of this volume while LRF accounted for the remaining 33%, the relative volumes for each estate were 474,765 m^3 and 234,738 m^3 respectively.

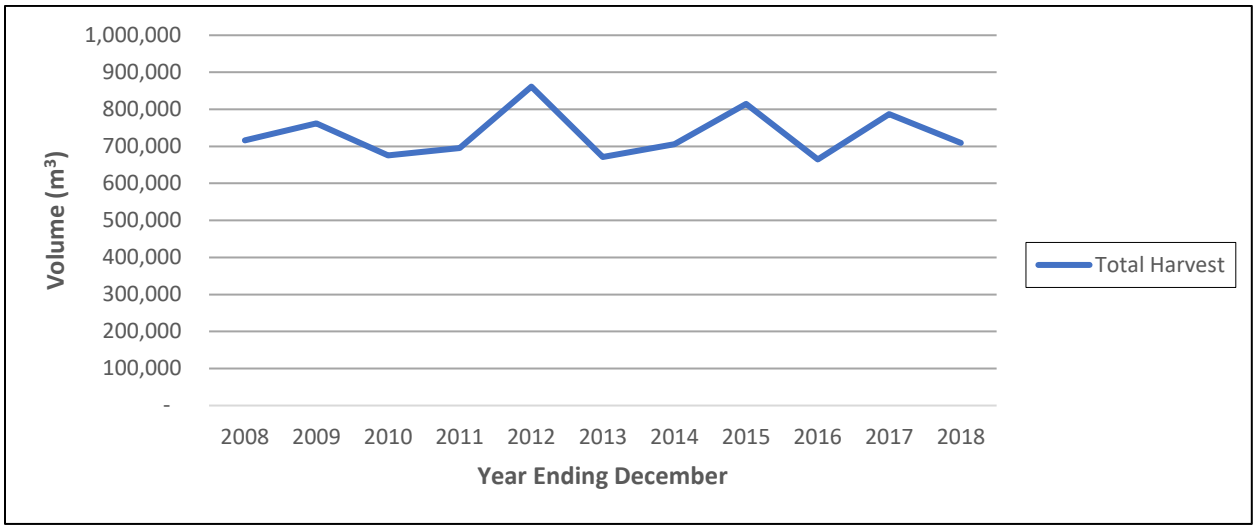

Figure 1: Combined annual Log sales from the Lake Taupo and Lake Rotoaira Forest estates.

The log grade mix of pruned, unpruned saw logs and pulp logs produced from both estates as a percentage of the annual log sales volume showed little variation over time, with unpruned saw logs always accounting for the largest percentage (Figure 2). Unpruned saw logs are the main log type sold from the trusts estate accounting for between 60-70% of the annual sales volume since 2008. Pruned logs have historically accounted for 10-20% of the annual sales volume while pulp logs have accounted for around 16-26%. Since 2016, the pulp log sales have fallen below pruned

log sales. As of 2018, the log grade mix was made up of 66% unpruned saw logs, 18% pruned logs and 16% pulp logs.

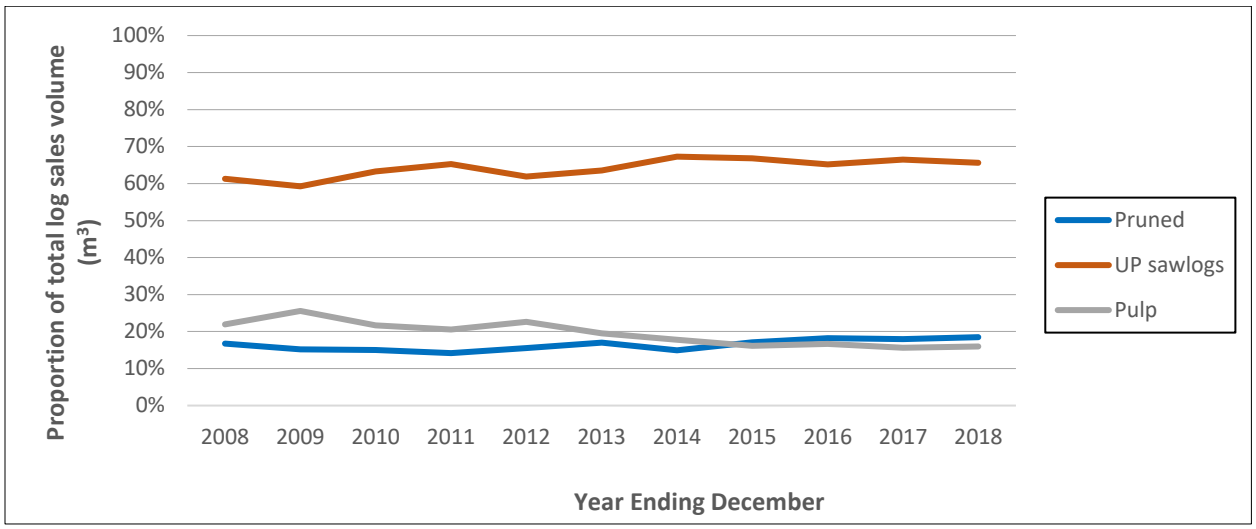

Figure 2: Log grade mix produced from the Lake Taupo and Lake Rotoaira Forest estates.

The demand from domestic and international customers is vital in terms of selling the log grade mix shown above. Figure 3 illustrates the percentage of annual log sales that is sold to the domestic and export market. The trends suggest that the domestic market has become less important while the export market has become more important. This is due to a greater percentage of unpruned saw logs being sold to the export market. In 2018, 63% of the annual log sales volume was sold domestically while the remaining 37% was exported.

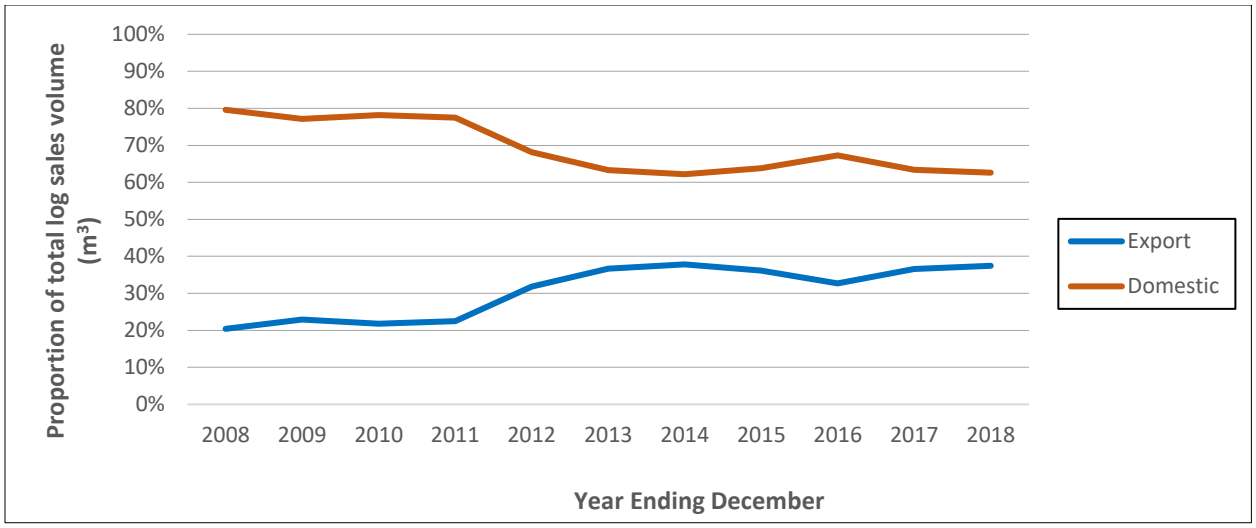

Figure 3: Percentage of annual log sales sold to the domestic and export market.

The historic trends illustrated in Figure 4, suggest that the percentage of unpruned saw logs sold to the domestic and export markets have changed over time. Between 2008 and 2012 most of the unpruned log sales were sold in the domestic market. However, this changed after 2012 with the export market taking a larger percentage of unpruned log sales. This trend flipped again in 2016, with export again taking more of the unpruned log volume.

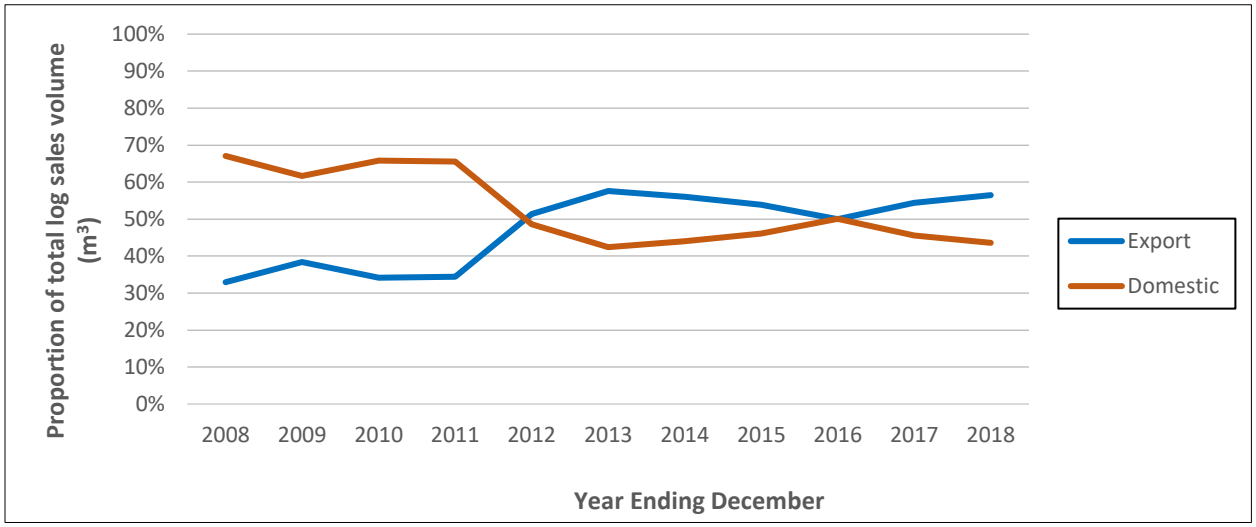

Figure 4: Percentage of unpruned sawlogs sold to the domestic and export market.

5.2 Domestic log demand

Pruned logs from the LTF and LRF estates sold to the domestic market ranged between nearly 120,000 m^3 in 2008 to just over 128,000 m^3 in 2018, with a maximum of 137,551 m^3 (Figure 5). The historic trends suggests that the demand for pruned logs has increased since 2008, which is a positive sign in terms of selling pruned logs in the future. In 2018, 128,386 m^3 of pruned logs was sold in the domestic market. The increase in pruned log demand suggests that domestic mills in the CNI process pruned logs successfully. Based on the historic trends, this demand is likely to continue, making the domestic market the main outlet for pruned logs. Almost 100% of the annual pruned log volume is sold domestically, with a minor percentage (1-3%) being sold to the export market in recent years for strategical marketing reasons. Pruned logs are mainly sold into China and Vietnam via a Korean customer.

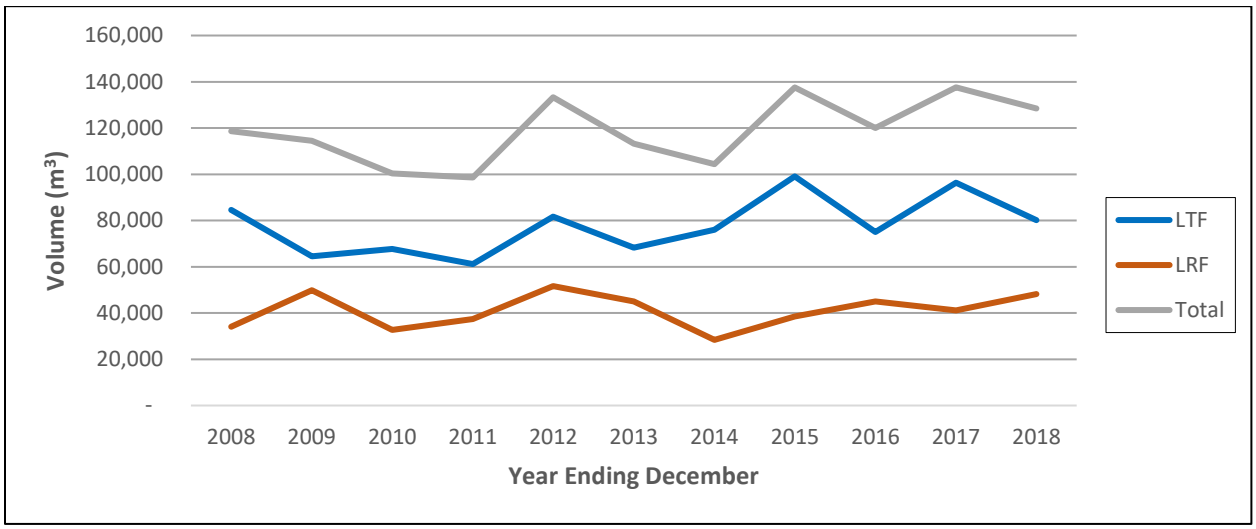

Figure 5: Volume of pruned logs sold to the domestic market.

Unpruned saw logs sold to the domestic market varied between a total of nearly 300,000 m^3 and 200,000 m^3 between 2008 and 2018 (Figure 6). In 2018, 202,625 m^3 of unpruned saw logs was sold to the domestic market which is significantly less than what was sold in 2008 (294,278 m^3). The general trend suggests that the supply of unpruned saw logs to domestic markets from the trusts forests will continue to decline as the percentage of this log type sold to the export market

continues to increase as shown in Figure 4. This further illustrates the point that mills in the CNI predominantly process pruned logs opposed to low grade structural logs.

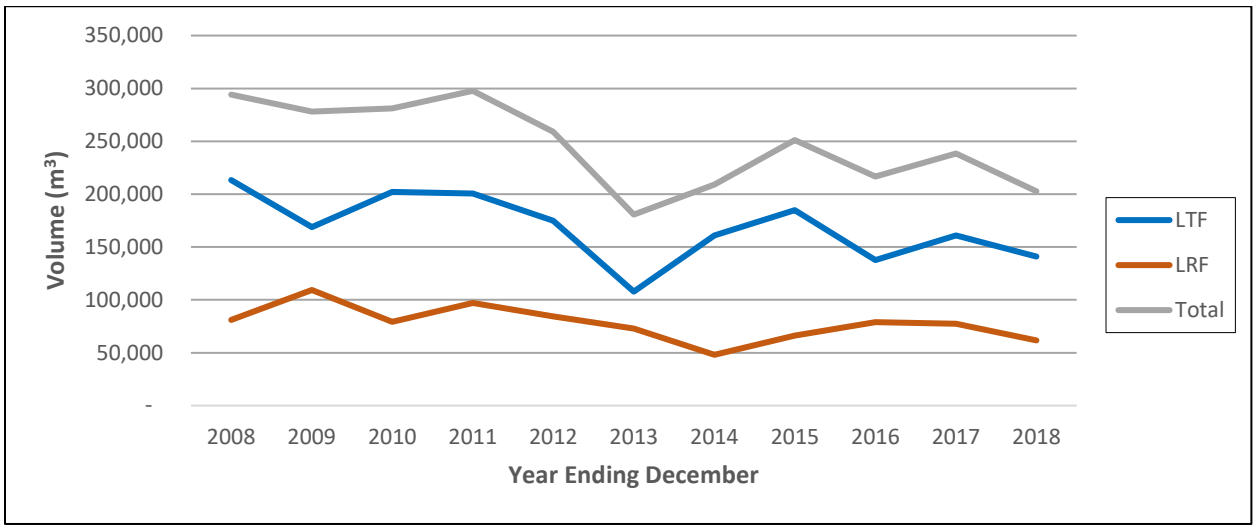

Figure 6: Volume of unpruned saw logs sold to the domestic market.

5.3 International log demand

The volume of pruned logs sold to the export market is minimal (maximum of 3,599 m^3) when compared to what is sold domestically (137,551 m^3), as shown in Figure 7. The appearance grade market seeks a pruned log which will provide a good finish, to meet this specification logs must be sawn as soon as possible to avoid the risk of sap stain. The pruned logs that are exported are debarked and anti-sap stained, but may still end up in the market with stain given the time taken to reach its international destination (typically 6 weeks from felling). There is only limited opportunities to sell pruned logs into the export market, therefore, the domestic market will remain the main outlet for pruned logs.

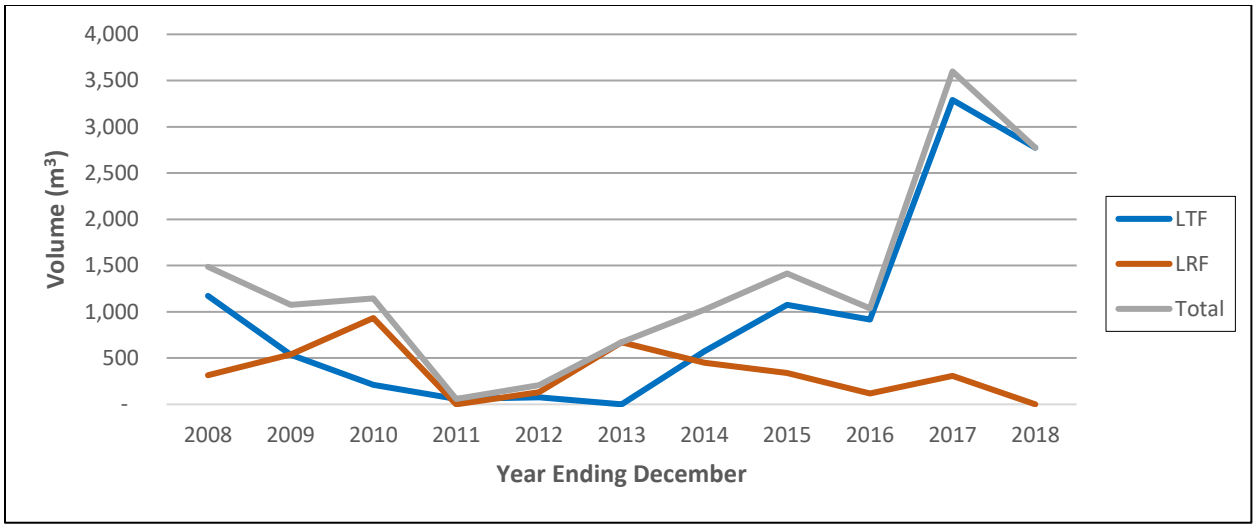

Figure 7: Volume of pruned logs sold to the export market.

Figure 8 illustrates the volume of unpruned saw logs sold to the export market from the LTF and LRF estates. As of 2018, the proportion of unpruned saw logs sold to the export market is greater than what was sold domestically. The demand for unpruned saw logs from the LTF and LRF estate is 169,295 m^3 and 93,398 m^3 respectively at the end of 2018. The historic trends suggest that unpruned saw logs will continue to be sold into the export market, making it an increasingly popular outlet for unpruned saw logs.

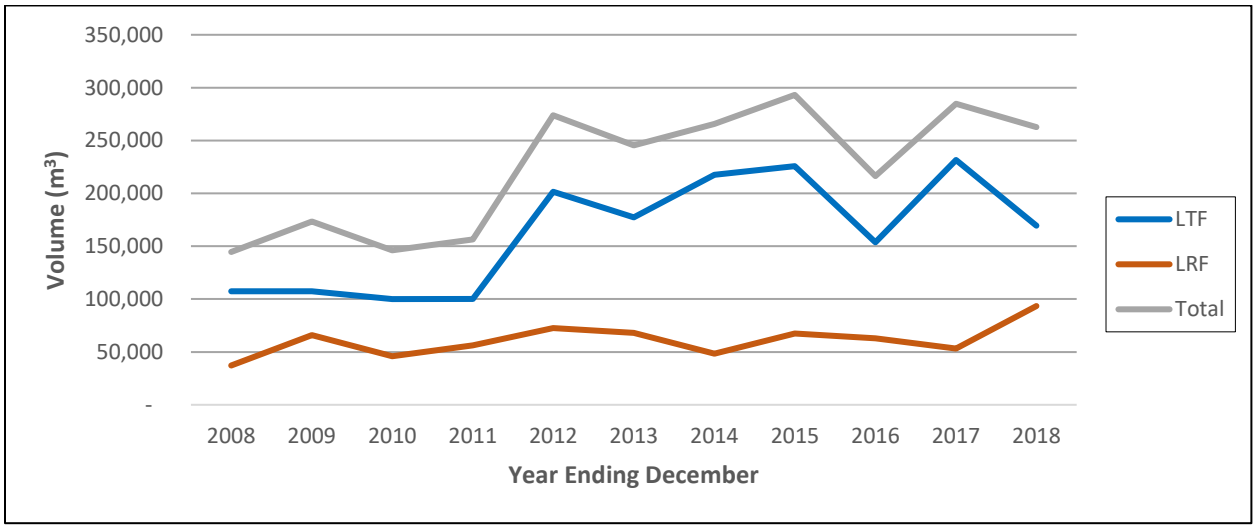

Figure 8: Volume of unpruned saw logs sold to the export market.

5.4 Domestic customers

Since 2007 the LTF and LRF estate supplied logs to various domestic customers, some of which have become more important over time while others became less important. Due to the sensitivity of this information only the totals by log type are shown here. The volume supplied by log type over a 12-month period between April 2018 and March 2019 has been totaled and split by the relevant customers to provide an indication of how many customers purchase each generic log type.

Over this period, the total sales volume of pruned logs was 126,056 m^3. This volume was sold to 10 customers in the CNI region, most of which exclusively process pruned logs with some having the capacity to also process high quality unpruned logs. Three of these customers purchased 68% of the total volume, which suggests there are three main pruned log customers in the CNI. The pruned log grades sold to these customers have a minimum SED of 350 mm and a length specification of 4.4/5.0 m and are commonly known as "PZ" logs.

The total domestic sales volume of unpruned saw logs over this period was 176,766 m^3. This volume was sold to 14 customers in and around the CNI region. Two of these customers combined purchased 46% of the total volume while another five customers combined purchased 47% of the total volume. The sale of pulp logs over this period was 109,520 m^3, which was sold to 10 customers in and around the CNI. Two of these customers purchased 96% of the total volume.

The domestic log sales between April 2018 and March 2019 suggest that there are three major pruned log customers, two major unpruned log customers and two major pulp log customers within the CNI. A number of smaller customers also exists taking a much small proportion of the trusts annual log sales volume. The major customers for each generic log type are vital in terms of selling the log grade mix produced from the trusts estate. The volume purchased by each of these customers has been stable over the previous 12-month period, however, wider consideration should be given to the relative market risk of having only a small number of major customers. The implications of this market risk will be discussed further.

5.5 Pruned log index

In theory, pruned log index should be considered when applying log prices to pruned log grades to account for differences in pruned log quality. Figure 9 illustrates the weighted average PLI achieved under each of the pruning regimes (two and three lift pruning), using a high quality site in LTF as an example. The results show that there is a clear difference in PLI between both regimes, with the three lift regime achieving a higher PLI overall. This shows that pruned logs under the three lift pruning regime should receive a higher price compared to logs produced under the two lift regime.

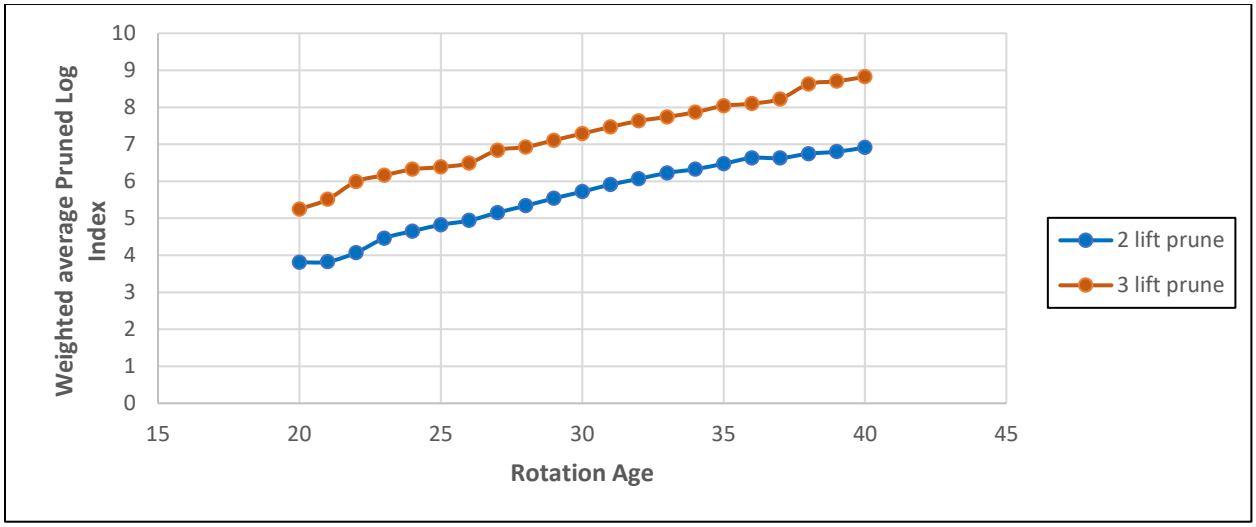

Figure 9: Weighted average pruned log index achieved on a high quality site in the Lake Taupo estate.

Park (1980) suggested that the value and grades produced from prune logs was influenced by three factors expressed as:

Pruned Log Index = (Diameter x Log conversion) / Defect core

The defect core component is the main driver behind the difference in PLI values achieved by each pruning regime. The three lift pruning regime generates a higher PLI than the two lift pruning regime due to the smaller defect core that is achieved by three pruning lifts. The development of the defect core under each regime is illustrated in Figure 10 for a high quality site in LTF. The size

of the defect core under the two and three lift pruning regimes is 231 mm and 197 mm respectively. The difference in the size of the defect core (34 mm) has driven the PLI values shown in Figure 9. The two lift regime achieves an even defect core across both pruning lifts compared to the three lift regime which achieves an uneven defect core between the first and second lift.

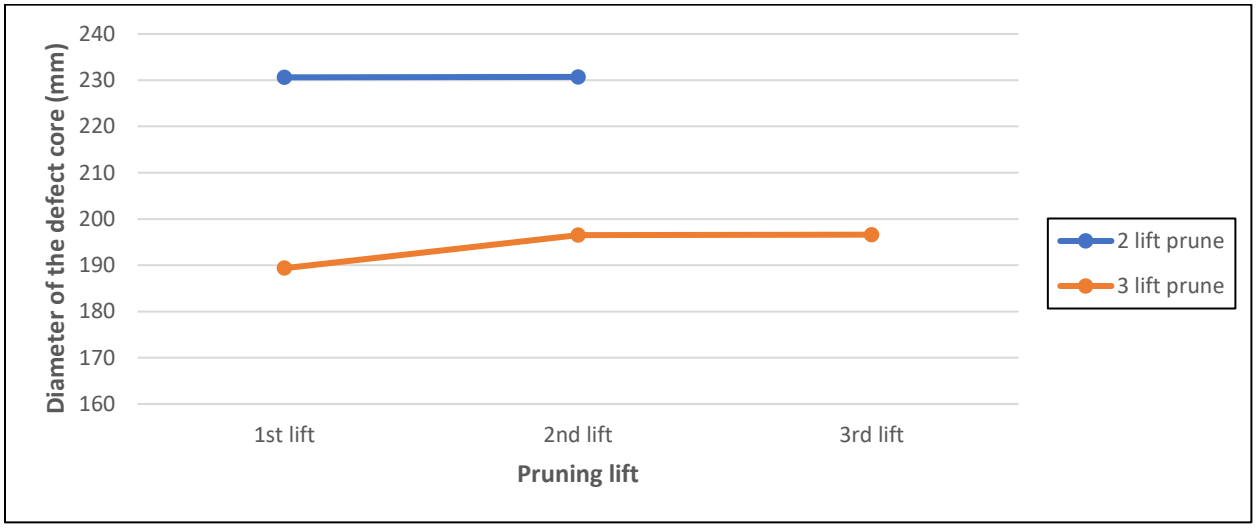

Figure 10: Defect core development of each pruning regime on a high quality site in the Lake Taupo estate.

5.6 On-truck log price

Table 1 shows the on truck log prices that have been used in the discounted cash flow analysis to evaluate the alternative silvicultural regimes. The on-truck log price has been calculated using the following variables for each log grade;

On-truck price ($/m^3) = (Revenue ($) – Transport cost ($)) / Volume (m^3)

The on-truck log price shown below are a 12-month average price between April 2018 and March 2019, which is assumed to be representative of the current market prices. The transport cost component has been subtracted from total revenue to bring all log grades back to a comparable pricing point (on truck).

This log price has been calculated based on customers that the LTFT and LRFT are currently supplying. The on-truck log price is driven by the relative location of each customer/market, which

influences the total transport cost for each log grade. Pruned log customers tend to be domestic customers located in close proximity to both estates, which generates a lower transport cost. Therefore, pruned log grades (PZ & PW) tend to have a relatively high on-truck log price. Transporting logs to unpruned log customers tends to generate a higher transport cost as these customers are located further away from the trusts' estates, for example, the Port of Tauranga and Port of Napier. Therefore, unpruned log prices have been adjusted for a higher transport cost. The transport costs component has driven the premium between pruned and unpruned log prices.

Table 1: 12-Month Average On-Truck Log Price by Grade ($/m³)

Log grade	On truck log price ($/m³)
PZ3.7	171
PZ5	171
PZ4.4	171
PW	116
UP	109
S30	109
A4.1	95
KS3.7	90
KI	84
RUA	30
RUH	28
Billets	19

5.7 Pruned log differential

To allow for a fair comparison between log prices, an on-truck log price has been calculated to remove the transport cost component. Figure 11 compares the on-truck log price between domestic pruned and export A grade on a quarterly basis. The export A grade price experienced extreme quarterly fluctuation, whereas the domestic pruned log price remained steady since September 2007. The historic trends show that the price of pruned logs increased up until March 2017, since then remained constant. A 12-month average price was calculated between April 2018 and March 2019 for each log grade as shown below. Based on the 12-month average the price differential sits at $76/m^3. This comparison illustrates the risk associated with selling A grade logs into the export

market, while highlighting the stability in the domestic pruned log price. A coefficient of variation (CV) has been calculated for each log grade to measure the relative variability of log prices from the long term average. The CV for pruned and A grade logs is 13% and 35% respectively, which illustrates that there is greater log price risk associated with selling A grade logs into the export market due to greater fluctuations in price. This is supported by the extreme quarterly price fluctuations illustrated below.

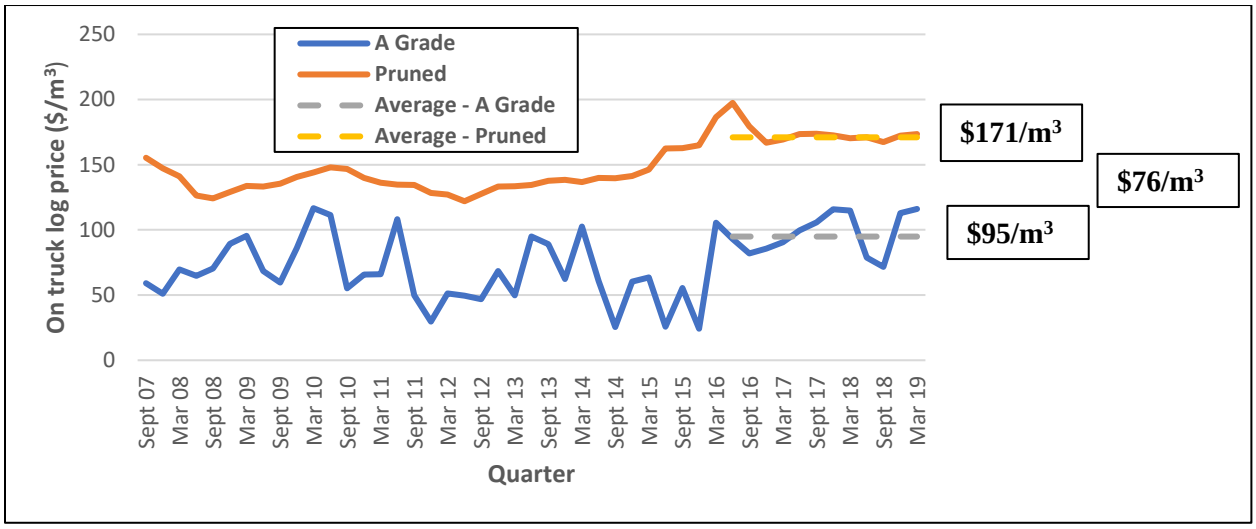

Figure 11: On-truck log price comparison between pruned and export A grade.

5.8 Silvicultural analysis

The Land Expectation Value (LEV) was used to assess the profitability of each regime across four sites within the LTF and LRF estate. LEV is the maximum price of bare land that a buyer can afford to pay for to achieve a required rate of return in forestry; in this case the required rate of return is 7%. The results are presented on a per hectare basis assuming flat terrain that can be harvested using a grapple skidder.

Table 2 shows the profitability of each regime in the LTF estate. The results show that the two lift pruning regime is the most profitable across all sites, followed by the unpruned and three lift pruning regimes. The difference in LEV between the two lift and unpruned regime increases as site quality increases, with the relative differences in LEV shown below:

- Low - $125/ha
- Medium – $279/ha
- High – $478/ha
- Very High – $419/ha

The difference in LEV is minimal on sites of low to medium productivity, which suggests that an unpruned regime would be better suited to these sites when considering the longer rotation ages under the two lift regime. On the high to very high productivity sites the two lift regime generates a much larger LEV compared to what it generates on low to medium productivity sites. The three lift pruning regime is the least profitable across all sites, which supports the trusts decision to shift away from the three lift regime in 2014.

Table 2: Maximum Land Expectation Value for the Lake Taupo Estate ($/ha).

Site Quality	Unpruned	Age	2 lift prune	Age	3 lift prune	Age
Low	3,148	27	**3,273**	**28**	1,243	28
Medium	4,368	25	**4,647**	**27**	2,238	25
High	5,348	26	**5,826**	**24**	5,133	26
Very High	6,746	22	**7,166**	**23**	6,365	24

Figure 12 compares the LEV for the most profitable regimes, assuming that an unpruned regime is best suited to low – medium quality sites while a two lift pruning regime is best suited to high-very high quality sites. The key findings from this analysis include:

- The unpruned regime on a low quality site generates a maximum LEV of $3,148/ha at age 27, while a maximum LEV of $4,368/ha at age 25 is generated on a medium quality site.
- The two lift pruning regime on a high quality site generates a maximum LEV of $5,826/ha at age 24, while a maximum LEV of $7,166/ha at age 23 is generated on a very high quality site.

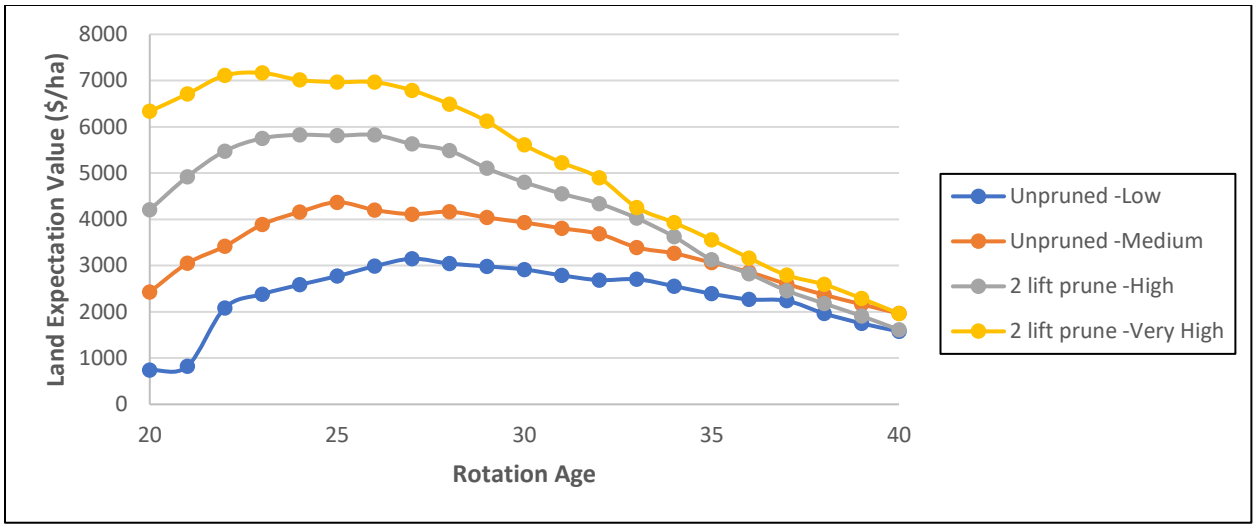

Figure 12: Land expectation value over time for the recommended regimes in Lake Taupo Forest.

Table 3 shows the profitability of each regime in the LRF estate. The trends in profitability are similar to what was found in LTF above, with the two lift regime being the most profitable followed by an unpruned and three lift regime. The relative difference in LEV between the two lift pruning and unpruned regime are shown below:

- Low - $391/ha
- Medium – $511/ha
- High – $787/ha
- Very High – $889/ha

Much like the LTF estate, the difference in LEV is minimal on sites of low to medium productivity. While on the high to very high productivity sites an additional gain in LEV of around $787/ha can be made under the two lift pruning regime. Again, the three lift pruning regime is the least profitable across all sites.

Table 3: Maximum Land Expectation Value for the Lake Rotoaira Estate ($/ha).

Site Quality	Unpruned	Age	2 lift prune	Age	3 lift prune	Age
Low	2,037	27	**2,429**	**28**	1,273	27
Medium	3,134	28	**3,645**	**27**	2,976	25
High	4,060	25	**4,847**	**26**	3,801	25
Very High	5,171	23	**6,061**	**23**	5,004	24

Figure 13 illustrates the LEV against rotation age for the most profitable regimes in the LRF estate. Coincidently, these regimes are the same for LTF and have been chosen on the same basis. The key findings from this analysis include:

- The unpruned regime on a low quality site generates a maximum LEV of $2,037/ha at age 27, while a maximum LEV of $3,134/ha at age 28 is generated on a medium quality site.
- The two lift pruning regime on a high quality site generates a maximum LEV of $4,847/ha at age 26, while a maximum LEV of $6,061/ha at age 23 is generated on a very high quality site.

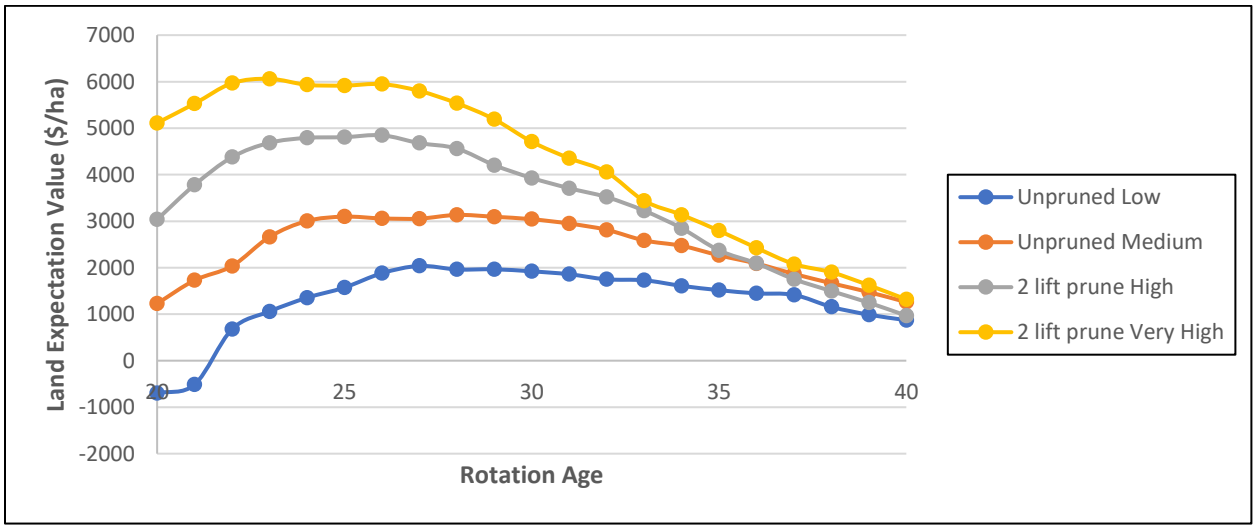

Figure 13: Land expectation value over time for the recommended regimes in Lake Rotoaira Forest.

Table 4 shows the Total Recoverable Volume (TRV) under each regime based on site quality. The unpruned regime generates a greater TRV across all sites, with an average TRV of 812 m^3/ha. The two and three lift pruning regimes generate similar TRV across all sites, with an average TRV of 711 m^3/ha and 705 m^3/ha for the two and three lift regimes respectively. The difference in TRV between the pruned and unpruned regimes is a direct result of the difference in final crop stocking (shown as 330 stems/ha and 450 stems/ha for a pruned and unpruned regime respectively). This illustrates the sacrifice in total volume per hectare when implementing a pruning regime.

Table 4: Total Recoverable Volume (m^3/ha) at Age 28 for the Lake Taupo and Lake Rotoaira estate.

Site Quality	Unpruned	2 lift prune	3 lift prune
Low	705	612	604
Medium	782	683	678
High	850	744	737
Very High	912	808	804
Average	**812**	**711**	**705**

Note. Total recoverable volume (m^3/ha) extracted from yield tables generated from site specific data using Forecaster.

Based on LEV the two lift pruning regime is more profitable across all sites in both estates, however, it should be noted that the analysis has some bias towards the two lift regime as log prices do not account for PLI predictions. The difference in LEV between the two lift and unpruned regime is driven by the log grades produced (pruned, unpruned, pulp) and the corresponding log price of each grade. Generic log types produced under the two lift pruning regime on a low quality site in the LTF estate showed that unpruned logs made up the largest volume, followed by pruned logs, and then pulp logs had the lowest volume (Figure 14). This general trend was apparent across all sites (only a low quality site is illustrated in Figure 14). Based on a rotation age of 28 years, unpruned log grades account for 57% of the TRV while pruned log grades account for 28%. The volume of pruned logs produced is the driving force behind the gain in LEV under the two lift regime, as these log grades are sold for a higher price in comparison to unpruned log grades. Pruned logs are not produced under the unpruned regime, therefore, the LEV is driven by the sale of a larger proportion of unpruned log grades (unpruned log grades account for 82% of TRV at age 28).

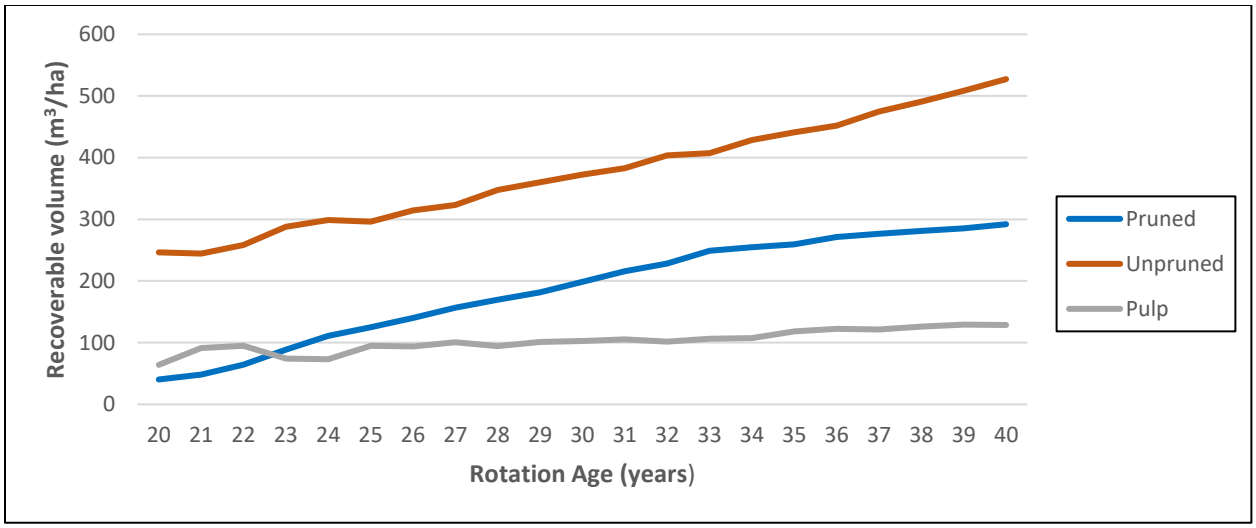

Figure 14: Generic log grades produced under the two lift pruning regime on a low-quality site

5.9 Sensitivity analysis

Figure 15 illustrates the difference in LEV between the two lift pruning regime and an unpruned regime in response to changes in discount rate. The results suggest that the profitability of each regime is driven by site quality and discount rate. The two lift pruning regime is more profitable at discount rates less than 8%, while the unpruned regime is more profitable at discount rates greater than 8%. Discount rates above 8% tend to produce shorter rotations which does not yield an adequate volume of pruned logs for the two lift regime to be profitable. Under the base case discount rate of 7% the two lift regime is more profitable across all sites.

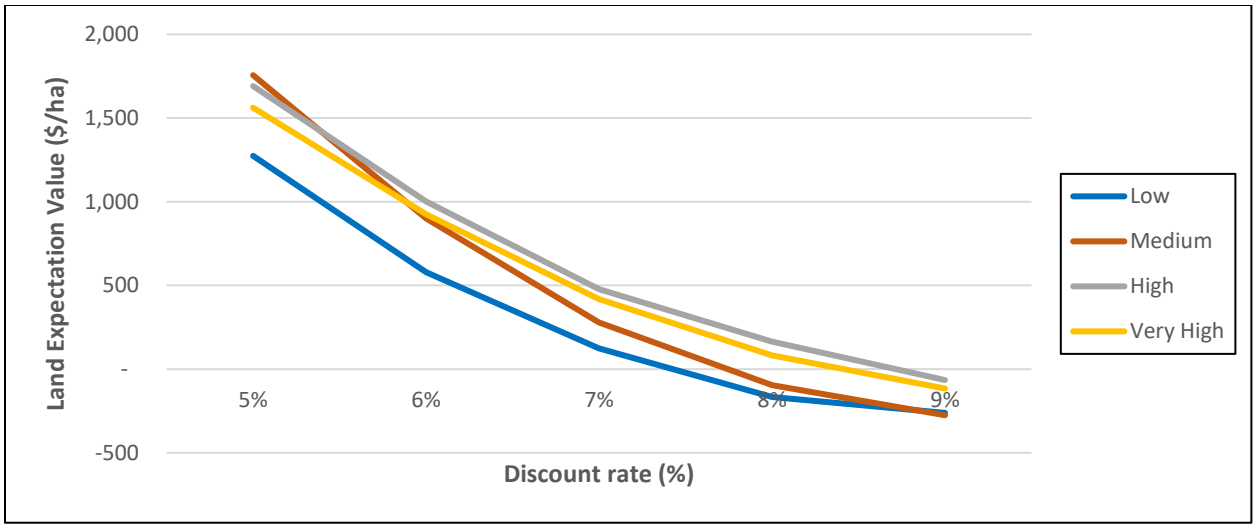

Figure 15: Sensitivity of land expectation value to changes in discount rate

Figure 16 illustrates the difference in LEV between the two lift pruning regime and an unpruned regime in response to changes in pruned log prices. The pruned log prices have been adjusted by equal increments while maintaining the base case prices for the unpruned log grades. The analysis has shown that the unpruned regime becomes more profitable when pruned log prices decline by more than 10%. The base case PZ and PW log price is $\$170/m^3$ and $\$116/m^3$ respectively. The analysis has shown that once these prices decline to $\$153/m^3$ (PZ) and $\$104/m^3$ (PW) pruning no longer becomes profitable, making the unpruned regime a more appealing investment option. This suggests that pruned log mills need to purchase pruned logs at this premium price now, in order for forest growers to continue investing in pruning regimes.

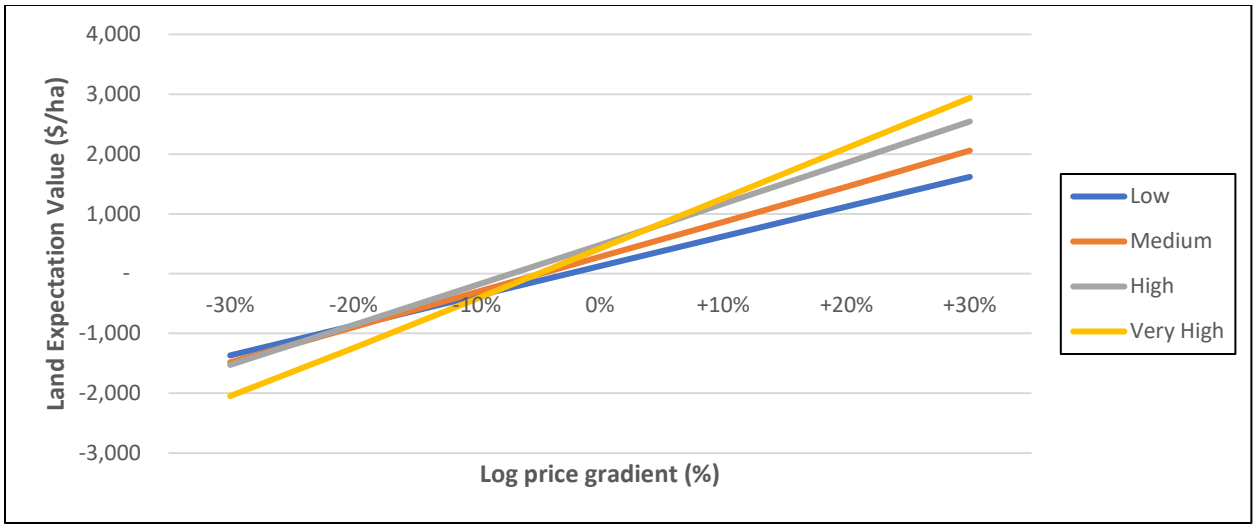

Figure 16: Sensitivity of land expectation value to changes in pruned log price.

Figure 17 illustrates the difference in LEV between the two lift pruning regime and an unpruned regime in response to changes in tending costs (year 0-10). The annual tending costs have been adjusted by the same percentage increments for each regime as shown below. The results show that the profitability of the two lift pruning regime decreases as silvicultural tending costs increase, site quality also has an influence on profitability. On the low and medium quality sites the unpruned regime becomes more profitable once tending costs increase by 10% and 20% respectively for a low and medium productivity site. The unpruned regime is more profitable on high to very high productivity sites once tending's costs increase by 30%. The two lift regime has higher tending costs during years 0-10 as a result of the two pruning lifts, therefore, the two lift regime carries an additional cost over the course of the rotation.

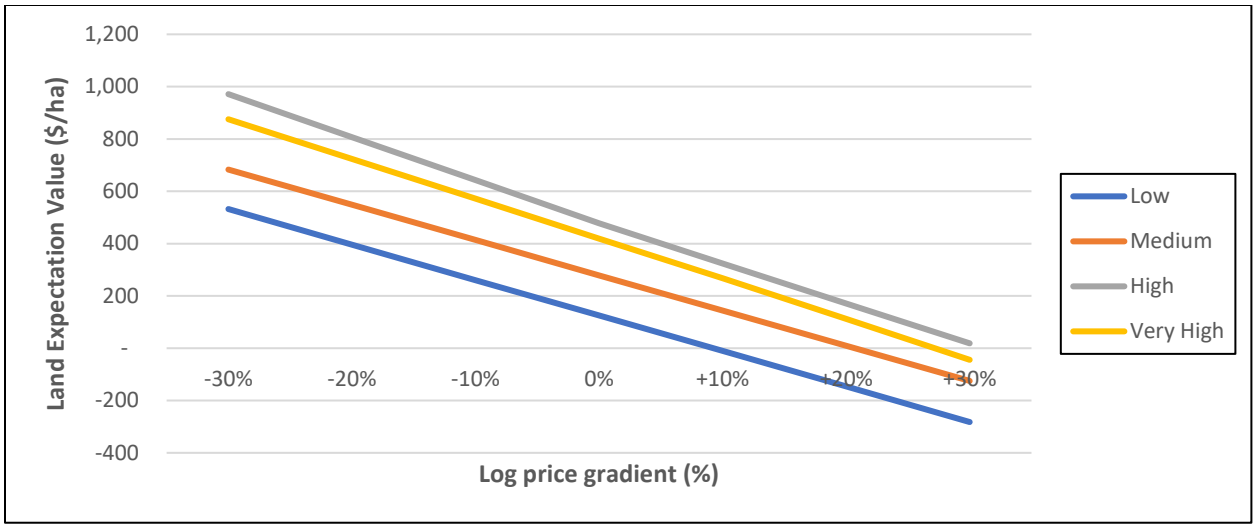

Figure 17: Sensitivity of land expectation value to changes in silvicultural tending costs

6. Discussion

This study aimed to investigate the following two areas associated with the silvicultural investment within the LTF and LRF estate;

- The demand for pruned, unpruned saw logs, and pulp logs from domestic and international customers
- Silvicultural regimes that best match 4 site types in the LTF and LRF estates, based on productivity using 300 index values (low (27), medium (29), high (31), and very high (33))

The main outlet for pruned logs is the domestic market while unpruned logs were mainly exported. In general, the analyses showed that the two lift pruning regime is a profitable option for these estates under the current assumptions. The results and findings of the study will have implications at an estate level which will need to be further analysed.

6.1 Domestic and international demand

Pruning has been a major part of the management carried out in the LTF and LRF estate, as shown by a high proportion of pruned area in each estate. Pruning has diversified the log grade mix produced, which allows the trusts to sell logs to a range of domestic and international customers. Unpruned logs are the main log type produced followed by pruned logs and then pulp logs. The trends in log sales show that the export market is becoming increasingly important while the domestic market is becoming less important. This is driven by a large proportion of unpruned saw logs being sold to the export market.

The main outlet for pruned logs is the domestic market, as almost 100% of the trusts pruned log supply is sold domestically. The demand for pruned logs is driven by the domestic mills which predominantly process pruned logs with some also processing structural logs (Tombleson, 2018). The appearance grade market is based on a good finish of the final wood product, as a result pruned log customers require pruned logs to be delivered no longer than two weeks after felling. This ensures that the logs are fresh, which helps with sawing and the final finish. This also reduces the risk of sap stain. A small portion of pruned logs (1-3%) are sold to the export market. These

logs are debarked and anti-sap stained to avoid the risk of sap stain. However, given that the time taken to reach its final destination (up to 6 weeks) logs may still end up in the market with stain. With this in mind, the domestic market will remain the main outlet for pruned logs.

The proportion of unpruned saw logs sold to the export market indicates that it is becoming the main outlet for unpruned saw logs. Currently, 56% of the annual unpruned log supply from these estates is being sold to the export market while the remaining 44% is being sold domestically.

It can be argued that pruning provides a greater diversity of markets for a forest grower, with the ability to sell logs to both the domestic and export market. Sawmills within the CNI predominantly buy pruned logs, but some of these mills also buy a small proportion of high quality unpruned saw logs.

6.2 Silvicultural analysis

The results from the analysis have been generated with log prices that do not account for PLI predictions in each of the pruning regimes. This tends to artificially favor the two lift regime, as the operational costs have been reduced but the log prices have not been adjusted for a lower PLI. This is a key driver for the difference in LEV between the two and three lift pruning regimes. The results suggest that pruning should be confined to the higher productivity sites which yield a higher volume of pruned log grades. Site quality is the key driver behind diameter growth which is important in a pruned regime to maximise clearwood growth. The lower quality sites are best suited to an unpruned regime given that the gain in LEV under the two lift regime would not warrant the additional wait in rotation age. The three lift regime is the least profitable across all sites, which supports the trusts decision to shift to the more profitable two lift regime. The profitability of the three lift regime suggests that it is unlikely to be re-implemented in the future.

There is a positive trend between site quality and LEV, as LEV increases with site quality. The two lift regime generates a higher LEV across all sites, which indicates that under the current log price assumptions the value of pruning the butt log compensates for the loss of volume per hectare. The two lift regime is more profitable as a result of the volume of pruned log grades produced which sell for a premium price over unpruned log grades.

6.3 Management implications

The current management strategy in the LTF and LRF estates involves the use of a two lift pruning regime and an unpruned regime, which is producing a mixture of pruned, unpruned saw logs and pulp logs. Incorporating the two lift pruning regime into the management of LTF and LRF provides additional employment for local people. If pruning is included silvicultural contractors can provide continuous work all year round in conjunction with planting, thinning and fire control. This gives New Zealand Forest Managers (NZFM) a competitive advantage over other forestry companies when labour becomes an issue around the time of planting.

Given that pruning operations continue within the Trust's estate, it would be recommended that it was undertaken using the two lift regime on sites of high to very high productivity. This is recommended on the basis that the two lift regime generates a significantly larger LEV on these sites. The decision to continue pruning will also ensure employment for some local people, which is valued by the forest trusts.

If pruning operations were to stop within the LTF and LRF estate, there would be negative implications on local employment and the overall pruned log supply within the CNI which will eventually affect domestic sawmills.

6.4 Regional implications

The decline in pruned area within the CNI will have significant implications for the 12 pruned log mills and one plymill located within the CNI. The implications will vary based on the relative size and market position of each mill. The decline in pruned log supply could potentially lead to a loss of 1,050 jobs at pruned log mills. This has been calculated under the assumption that the pruned log supply will decline by 70%, with no intervention (MBIE, 2018). This decline is largely driven by Timberlands decision in 2015 to stop pruning.

The current consumption of pruned logs in the CNI is around 1.226 million m^3 as of 2017 (Tombleson, 2018). Scenario 3 of the Wood Availability Forecast has been modelled under the assumption that large-scale owners harvest at stated intentions then at non-declining yield with

total wood availability being modelled at a split non-declining yield. Under this scenario the pruned wood supply in the CNI can sustain this level of consumption until 2027 at which point the recoverable pruned log volume will be in decline until 2050. The adverse effects of this decline will be felt by domestic mills before 2027 as some mills will be forced to reduce capacity in order to survive. The decline in pruned log supply will cause sawmills to make drastic changes within the next decade in terms of processing capabilities. Some mills within the CNI exclusively process pruned logs with limited capacity to process unpruned logs. This will cause some mills to reconfigure their processing lines to process structural/industrial grade logs to offset the decline in pruned log intake (MBIE, 2018).

6.5 Limitations

The analysis has evaluated two alternative pruning regimes; two lift pruning and three lift pruning. The analysis has assumed the same log prices for both regimes, which does not account for PLI predictions. PLI is a measure of pruned log quality from which the log price should be based on. In theory, the three lift regime will produce pruned logs with a smaller defect core, therefore, log prices should be adjusted for a better PLI. Figure 10 above compares the defect core development between the two and three lift pruning regimes on a high quality site in LTF. This graphically illustrates the smaller defect core that is achieved using a three lift pruning regime. Therefore, the comparison between the two and three lift pruning regimes artificially favors the two lift regime, as the log prices do not account for the better PLI that is achieved under the three lift regime.

Given that the decision to prune or not to prune impacts the future financial returns it would be useful to analyse the profitability of pruning under historic price situations. The analysis has used on truck log prices/price differentials over a 12-month period between April 2018 and March 2019 which illustrate the current price situation. Historic price situations have been excluded from the analysis. Using historic price situations would provide an indication of the trusts more immediate financial returns from their silvicultural investments.

7. Conclusion & recommendations

The primary goal of this project was to evaluate the profitability of alternative silvicultural regimes in the Lake Taupo and Lake Rotoaira Forest estates. The following silvicultural regimes were considered; unpruned, two lift pruning and three lift pruning. The analysis has shown that the two lift pruning regime is the most profitable regime across all sites within both estates followed by an unpruned regime. The traditional three lift regime proved to be the least profitable in all cases which supports the trusts decision to move towards a more profitable regime (two lift prune) in 2014.

The unpruned regime was better suited to sites of low to medium quality as there was very little gain in LEV if a pruning regime is implemented on these sites. The two lift regime was better suited to sites of high to very high quality as these sites produced a greater volume of pruned log grades which generated a greater gain in LEV. Tombleson (2018) catergorised the LTF and LRF as medium sized pruned log suppliers. He later concluded that medium/small scale suppliers would be unlikely to transition towards unpruned regimes as a results of higher cost structures, where the pruned log component is vital in terms of making forestry a viable investment. The results from this study are somewhat conflicting with Tombleson's findings, as this study showed a shift towards unpruned regimes is a profitable option in both estates. However, this decision needs to be considered at an estate level opposed to a stand level which this study is based on.

Markets are an important aspect in terms of selling the log grade mix produced from the trusts estate. The CNI region currently shows a healthy demand for pruned logs given that 100% of the trusts pruned log supply has the potential to be sold domestically. This suggests that domestic sawmills are likely to continue processing pruned logs in the future. There is a limited capacity to sell pruned logs into the export market.

In 2018, Tombleson identified that most of the mills within the CNI process pruned logs with only a handful being able to process structural logs. With the decline in pruned log supply in the CNI some mills will be forced to upgrade their processing lines to process unpruned logs. If these mills choose to upgrade towards processing structural logs then the domestic demand for pruned logs will be reduced significantly.

The mission statements of both forest trusts are largely focused around benefitting the owners and their descendants. The Lake Taupo mission statement is as follows:

"To realise the dreams of those who have gone before us by fulfilling their expectations to build a competitive business, respect their customary values, and protect their lands and assets in order to deliver real benefits to their descendants"

Benefit can be delivered in a variety of different ways, with pruning operations providing employment and cash flow through the distribution of annual dividends. With this in mind the decision to continue pruning will be influenced by more than just profitability. Factors such as employment and cash flow will need to be considered as these are highly valued by both forest trusts.

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9. Appendices

9.1. Appendix 1

Appendix 1: Definitions

LTF = Lake Taupo Forest

LRF = Lake Rotoaira Forest

LTFT = Lake Taupo Forest Trust

LRFT = Lake Rotoaira Forest Trust

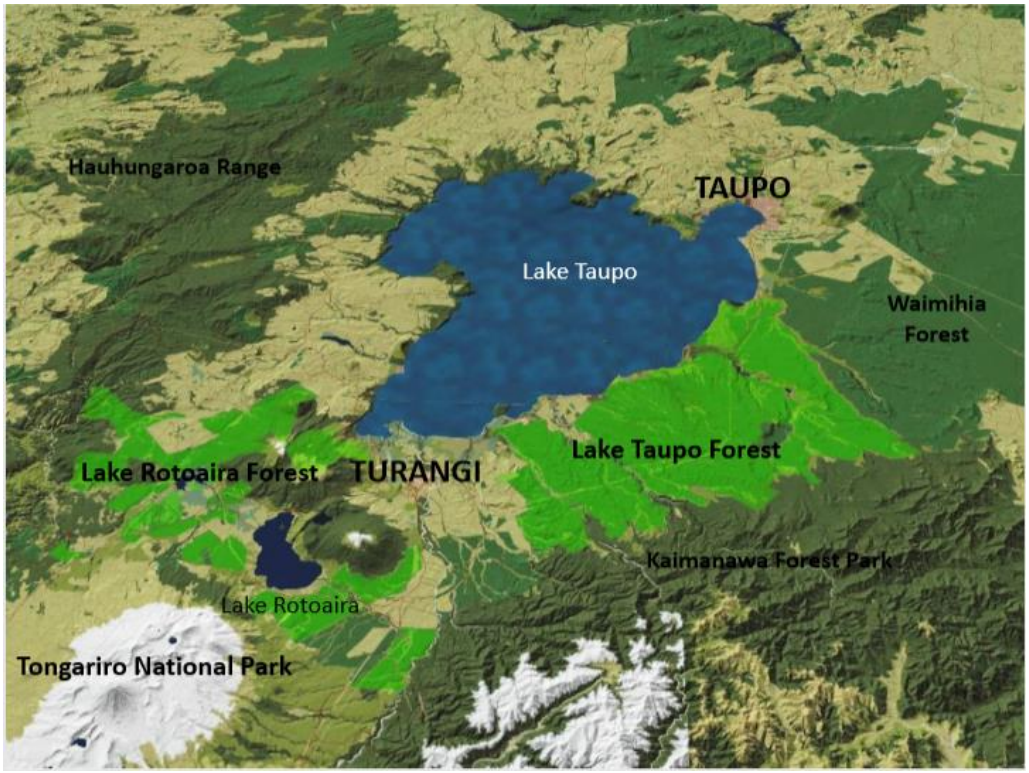
LEV = Land Expectation Value

TRV = Total Recoverable Volume

PLI = Pruned Log Index

9.2. Appendix 2

Appendix 2: Geographic location of Lake Taupo and Lake Rotoaira Forest.



9.3. Appendix 3

Appendix 3: Log grade specifications

Log grade	MinSED (mm)	MaxSED (mm)	MaxLED (mm)	Branch size (mm)	Max Sweep (%)	Length (m)
PZ 5	350	950	950	0	25	5
PZ 4.4	350	950	950	0	25	4.4
PZ 3.7	350	950	950	0	25	3.7
PW	350	900	900	140	25	5
UP	350	950	950	70	25	5.2
S30	300	900	500	70	25	4.9, 5.5, 6.1
A 4.1	300	550	550	140	25	4.1
KS 3.7	200	500	500	140	25	3.7
KI	260	999	999	140	25	3.7
RUA	100	400	400	0	100	3-8
RUH	350	850	850	0	100	3-8
Billets	100	850	850	0	100	0.8-3

Appendix 3: Cutting strategy used in Forecaster.

Log Product Definitions

Order	Name	Description	Price ($)	Priority
0	PZ5	Pruned		1
1	PZ4.4	Pruned		2
2	PZ3.7	Pruned		3
3	PW	Part Pruned, Sawlog (2m prune...		4
4	UP			5
5	S30			6
6	A4.1			7
7	KS3.7	Large branch, Small diameter s...		8
8	KI	Large branch, Small diameter s...		9
9	RUA	Pulp		10
10	RUH	Pulp		11
11	Billets	Pulp		12

9.4. Appendix 4

Appendix 4: 12 month average on truck log prices used in discounted cash flow analysis.

Log grade	On truck log price ($/m³)
PZ3.7	171
PZ5	171
PZ4.4	171
PW	116
UP	109
S30	109
A4.1	95
KS3.7	90
KI	84
RUA	30
RUH	28
Billets	19

9.5. Appendix 5

Appendix 5: Lake Taupo Silvicultural costs ($/ha) used in discounted cash flow analysis (years 0-10)

3 lift prune:

Site Quality	VERY HIGH	HIGH	MEDIUM	LOW
0	1442	1442	1442	1442
1	79	79	79	79
2	28	28	28	28
3	0	0	0	0
4	1098	0	0	0
5	778	1098	1098	0
6	0	778	0	1098
7	749	0	778	778
8	549	749	0	0
9	0	549	749	749
10	0	0	549	549

2 lift prune:

Site Quality	VERY HIGH	HIGH	MEDIUM	LOW
0	1442	1442	1442	1442
1	79	79	79	79
2	28	28	28	28
3	0	0	0	0
4	179	0	0	0
5	1098	1276	179	0
6	0	0	1098	1276
7	799	799	0	0
8	0	0	799	799
9	549	549	0	0
10	0	0	549	549

Unpruned:

Site Quality	VERY HIGH	HIGH	MEDIUM	LOW
0	1442	1442	1442	1442
1	79	79	79	79
2	28	28	28	28
3	0	0	0	0
4	179	0	0	0
5	0	179	0	0
6	0	0	179	179
7	0	0	0	0
8	587	0	0	0
9	0	587	0	0
10	0	0	587	587

Appendix 5: Lake Rotoaira Silvicultural costs ($/ha) used in discounted cash flow analysis (years 0-10)

3 lift prune:

Site Quality	VERY HIGH	HIGH	MEDIUM	LOW
0	1642	1642	1642	1642
1	68	68	68	68
2	69	69	69	69
3	0	0	0	0
4	934	0	0	0
5	758	934	934	0
6	0	758	0	934
7	896	0	758	758
8	637	896	0	0
9	0	637	896	896
10	0	0	637	637

2 lift prune:

Site Quality	VERY HIGH	HIGH	MEDIUM	LOW
0	1642	1642	1642	1642
1	68	68	68	68
2	69	69	69	69
3	0	0	0	0
4	0	0	0	0
5	1066	1066	1066	0
6	0	0	0	1066
7	729	729	729	0
8	0	0	0	729
9	637	637	0	0
10	0	0	637	637

Unpruned:

Site Quality	VERY HIGH	HIGH	MEDIUM	LOW
0	1642	1642	1642	1642
1	68	68	68	68
2	69	69	69	69
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	130	130	130	130
7	0	0	0	0
8	575	0	0	0
9	0	575	0	0
10	0	0	575	575

9.6. Appendix 6

Appendix 6: Harvesting cost model (skidder based system)